

Name: \_\_\_\_\_ Date: \_\_\_\_\_

## Answer Key: Orbital Hybridization Odyssey for 11th Grade

Calculate formal charges and predict molecular geometries using VSEPR theory and hybridization models across complex polyatomic ions and resonance structures.

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**1. In the molecule Phosphorus Pentachloride ( $\text{PCl}_5$ ), what is the hybrid orbital set required to accommodate the expanded octet around the central atom?**

**Answer:** B)  $\text{sp}^3\text{d}$

Phosphorus in  $\text{PCl}_5$  has five bonding pairs and zero lone pairs, requiring five equivalent hybrid orbitals, which are formed by the hybridization of one s, three p, and one d orbital ( $\text{sp}^3\text{d}$ ).

**2. The bond angle in a Nitrogen Trifluoride ( $\text{NF}_3$ ) molecule is slightly less than 109.5 degrees due to \_\_\_\_\_.**

**Answer:** A) lone pair-bonding pair repulsion

According to VSEPR theory, the lone pair on the Nitrogen atom exerts greater repulsion than bonding pairs, squeezing the F-N-F bond angles to approximately 102 degrees.

**3. The molecule Benzene ( $\text{C}_6\text{H}_6$ ) contains localized pi bonds formed by the overlap of hybridized  $\text{sp}^2$  orbitals.**

**Answer:** B) False

Benzene features delocalized pi electrons in a ring system; the pi bonds are formed by the side-by-side overlap of unhybridized p-orbitals, not  $\text{sp}^2$  hybrids.

**4. Which of the following polyatomic ions exhibits the highest degree of resonance stabilization where all bond lengths are equivalent?**

**Answer:** C) Carbonate ( $\text{CO}_3^{2-}$ )

The Carbonate ion has three resonance structures that average out to a hybrid where each C-O bond is exactly 1.33 bonds, leading to equal bond lengths and shared charge across all three oxygen atoms.

**5. What is the formal charge on the central Sulfur atom in the Lewis structure of Sulfuric acid ( $\text{H}_2\text{SO}_4$ ) that minimizes formal charges?**

**Answer:** C) 0

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To minimize formal charges in  $\text{H}_2\text{SO}_4$ , the central sulfur forms two double bonds with non-hydrogenated oxygens and two single bonds with hydroxyl groups, resulting in a formal charge of 0.

**6. In Molecular Orbital (MO) Theory, the combination of two atomic 1s orbitals results in the formation of a low-energy bonding orbital and a high-energy \_\_\_\_\_ orbital.**

**Answer:** A) sigma-star antibonding

The destructive interference of atomic wave functions creates an antibonding orbital ( $\sigma^*$ ) which has a node between the nuclei and higher energy than the original atomic orbitals.

**7. A molecule with a square planar molecular geometry always possesses a central atom with  $sp^3d^2$  hybridization and two lone pairs.**

**Answer:** A) True

Square planar geometry (like in  $\text{XeF}_4$ ) arises from an octahedral electron geometry (six electron domains) where two domains are lone pairs, requiring  $sp^3d^2$  hybridization.

**8. The dipole moment of Boron Trifluoride ( $\text{BF}_3$ ) is zero because the \_\_\_\_\_ arrangement of the polar B-F bonds results in vector cancellation.**

**Answer:** B) Trigonal Planar

In a trigonal planar geometry, the three bond dipoles are oriented 120 degrees apart in a single plane, causing their vector sum to equal zero, making the molecule nonpolar.

**9. Which of these molecules contains exactly two pi bonds and one sigma bond between the carbon atoms?**

**Answer:** C) Ethyne ( $\text{C}_2\text{H}_2$ )

Ethyne (acetylene) features a triple bond between carbons. A triple bond consists of one sigma ( $\sigma$ ) bond and two pi ( $\pi$ ) bonds.

**10. The Lattice Energy of Lithium Fluoride (LiF) is lower than that of Magnesium Oxide (MgO) because the product of the ionic charges is smaller.**

**Answer:** A) True

Lattice energy is proportional to  $(k * Q_1 * Q_2) / r$ . Since LiF involves +1 and -1 charges (product = 1) and MgO involves +2 and -2 (product = 4), MgO has significantly higher lattice energy.